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Research Paper
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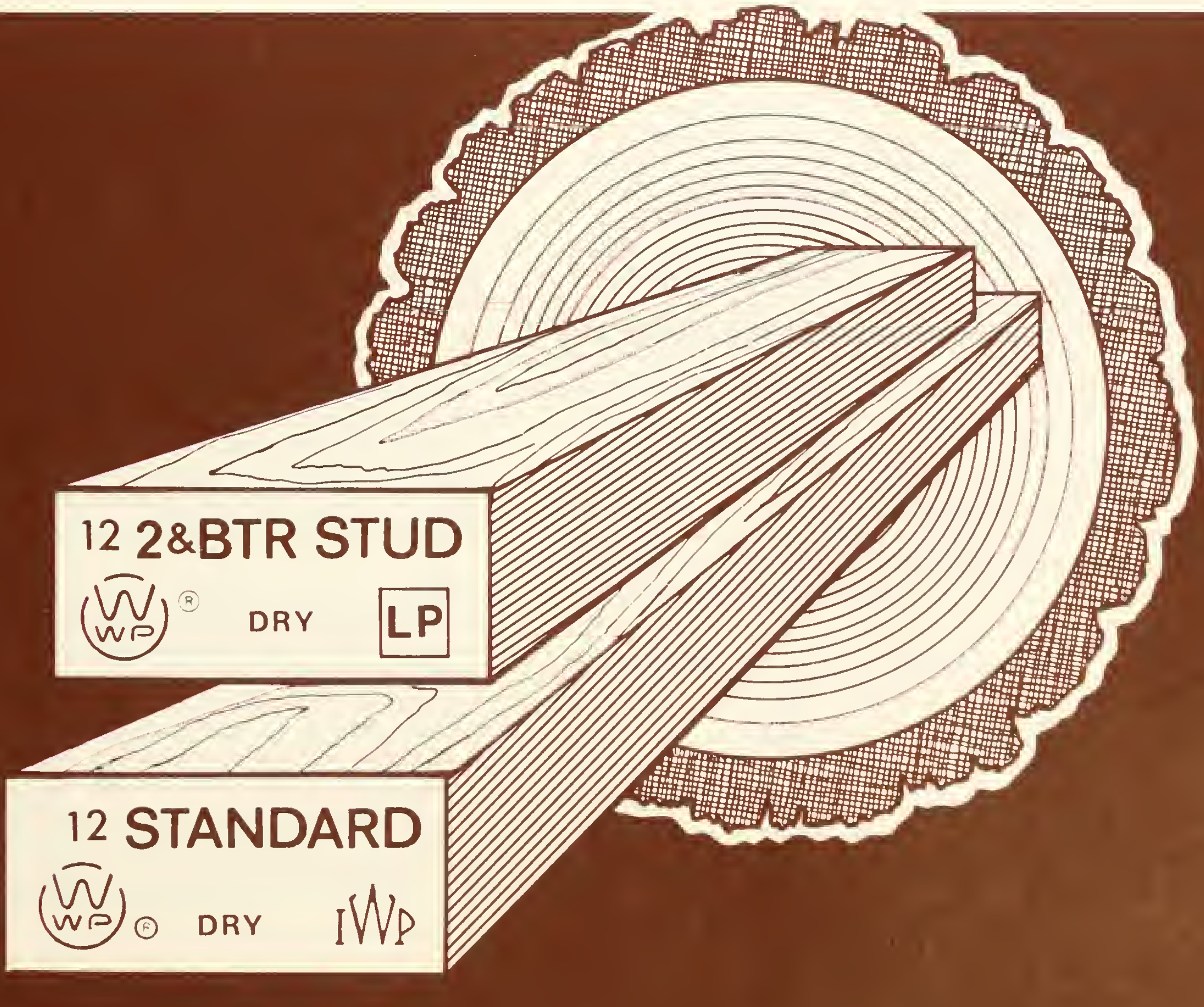
January 1982

Evaluation of Dimension Lumber Made from Dead-Tree Logs

David P. Lowery and Roy F. Pellerin



THE AUTHORS

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RESEARCH SUMMARY

Dimension lumber made from dead lodgepole and western white pine was evaluated nondestructively by the E-computer, and stress-wave testing methods. The same material was then tested on edge to failure. Analysis of the test data showed that the modulus of elasticity could be predicted fairly well by the nondestructive methods, and the results from the two methods were closely related. Test results showed no marked differences in moduli of elasticity between lumber cut from dead trees and lumber cut from live trees.

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INTRODUCTION

The Northern Rocky Mountain area contains a large number of dead trees, primarily lodgepole pine *(Pinus contorta* var. *latifolia* Engelm.) and western white pine *(Pinus monticola* Dougl.) that were killed by insect and disease epidemics. Some of these dead trees are being harvested as a part of green-timber sales. Thus logs from dead trees and green trees are mixed for processing and the resulting lumber is mixed for sales and use. The design loads of dimension lumber used in construction are based on the strength properties of green-tree lumber. There is, then, an urgent need to determine the comparable strength properties of dead-tree dimension lumber. As more of the dead trees are utilized, strength property knowledge becomes of greater importance.

Sinclair and coworkers (1979) found that the modulus of rupture and modulus of elasticity may be significantly reduced by incipient decay and associated sapstain as early as 2 months following foliage discoloration in beetle-killed southern pine. The report emphasizes the need for additional information on the strength characteristics of dead-tree lumber. The Rocky Mountains are colder and drier than the South and Atlantic seaboard; therefore, beetle-killed lodgepole and western white pine trees often remain standing and free of decay for years after their death.

As a part of its wood research program which relies on destructive test machinery, Washington State University has developed nondestructive testing equipment and procedures. The equipment measures the modulus of elasticity, from which corresponding values of the modulus of rupture can be assigned (Marra and others 1966; Pellerin 1965). Studies indicate that nondestructive testing can be used to evaluate log and lumber quality (Galligan and others 1967; Pellerin and Kern 1974). The availability of this nondestructive and destructive testing equipment provided an opportunity to investigate the strength properties of dead-tree dimension lumber.

The objectives of this study were: to obtain nondestructive data for dimension lumber from dead lodgepole and western white pine trees; to test to failure a sample of the dead-tree lumber; and to establish the relationship between nondestructive and destructive test values.

TEST PROCEDURE

Dimension lumber of two species of dead trees, lodgepole pine and western white pine, was used in this study. The lodgepole pine lumber was obtained from a sawmill in western Montana and the white pine lumber from a sawmill in northern Idaho.

Logs for both species were cut from trees that had been dead for various periods of time. The lodgepole logs were segregated in the mill yard and processed through the mill as a batch in accordance with the mill's usual operating procedure; however, the production of dimension lumber was favored. Both nominal 2 by 4's and 2 by 6's (5 by 10 cm and 5 by 15 cm) were made from the logs. All the dimension lumber produced from the batch of dead logs was set aside at the green chain. The lumber was not graded, but as the sample included all the pieces from the log batch, the grade distribution was considered representative of material made from dead-tree logs. The distribution by size and length of the 148-piece sample was as follows:

Nominal size	Length in feet				
	16 (4.9 m)	14 (4.3 m)	12 (3.7 m)	10 (3.1 m)	8 (2.4 m)
2 × 6 (5 × 15 cm)	8	10	12	8	
2 × 4 (5 × 10 cm)	20	27	40	20	3
Total	28	37	52	28	3

The dead white pine logs were obtained from trees included in a grade recovery study for the species. A variety of boards as well as 2 by 4 (5 by 10 cm) dimension lumber was cut from the logs. All of the grade recovery study material was kiln dried, surfaced, and graded. The dimension lumber from the dead trees was sampled at the dry chain after the pieces had been sorted into piles by grade. An effort was made to select representative pieces that had various types of defects and also to distribute the pieces by length and grade. The distribution of the 238-piece sample by grade is shown in the following tabulation:

Grade	**Length in feet**				
	16 (4.9 m)	**14 (4.3 m)**	**12 (3.7 m)**	**10 (3.1 m)**	**8 (2.4 m)**
Construction and better	38	10	8	2	3
Standard	28	29	19	3	1
Utility	32	13	11	5	0
Economy	14	5	9	8	0
Total	112	57	47	18	4

The two lumber samples were transported by truck to the university. Here, tests indicated the lodgepole sample was too wet for evaluation so the material was stickered and piled in a greenhouse-type dryer for approximately 3 months. The white pine sample was also stickered and piled indoors for a few weeks to permit the pieces to attain equilibrium moisture content before testing. The moisture content of all lumber at the time of test was 6 to 7 percent. The lodgepole lumber was surfaced to nominal size before testing.

After conditioning, each board was nondestructively evaluated with the E-computer, the stress-wave equipment, and the static bending method. The E-computer calculates the modulus of elasticity of a board from its resonant frequency while supported near its ends. The longitudinal stress-wave method determines the modulus of elasticity of the board from the velocity of propagation of a stress wave passing longitudinally through the board and the density of the board (Pellerin 1965; Kaiserlik and Pellerin 1977).

After nondestructive testing, each board was tested on edge to failure in flexure according to ASTM D198 standards (ASTM 1974). Specimens were cut from each piece for determination of moisture content and specific gravity. Percentage of moisture content was determined by the ovendrying method and the specific gravity was based on green volume and weight.

RESULTS AND DISCUSSION

A summary of the nondestructive and destructive tests for lodgepole pine by size and length is shown in table 1. For the 2-by-6-inch (5-by-15-cm) lumber the average modulus of elasticity by the computer method (Ec) was 1.38×10^6 (9.5 GPa), with a range in values from 0.91×10^6 to 2.04×10^6 (6.27 to 14.07 GPa); the average modulus of elasticity by the stress wave method (Esw) was 1.67×10^6 (11.5 GPa), with a range from 0.98×10^6 to 2.66×10^6 (6.76 to 18.34 GPa) and the modulus of elasticity by the static bending method (Es) was 1.31×10^6 (9.0 GPa), with a range in values from 0.76×10^6 to 2.6×10^6 (5.24 to 17.93 GPa). The average modulus of rupture was 4,984 pounds per square inch (psi) (34 363 kilopascals [kPa]). The Wood Handbook (1974) reports an average modulus of rupture value of 5,500 psi (38 921 kPa) and an average modulus of elasticity value of 1.08×10^6 psi (7.4 GPa) for lodgepole pine.

Table 1.—Results of nondestructive and destructive tests of lodgepole pine dimension lumber made from dead trees

			Average				
					Modulus of elasticity		
Size	Length	No. of pieces	Moisture content	Modulus of rupture	Computer	Stress wave	Static
Inches (cm)	*Feet (m)*		*Percent*	*Psi*	*Million psi*		
2 × 6 (5 × 15)	10 (3.1)	8	7.44	6,085	1.50	1.82	1.37
	12 (3.7)	12	7.98	5,386	1.38	1.72	1.47
	14 (4.3)	10	7.71	3,944	1.26	1.51	1.14
	16 (4.9)	8	7.51	4,583	1.41	1.66	1.24
Average			7.70	4,984 (34 363 kPa)	1.38 (9.5 GPa)	1.67 (11.5 GPa)	1.31 (9.0 GPa)
2 × 4 (5 × 10)	8 (2.4)	3	6.87	6,793	1.43	1.72	1.48
	10 (3.1)	20	6.52	4,695	1.23	1.49	1.17
	12 (3.7)	40	6.67	4,992	1.28	1.55	1.21
	14 (4.3)	27	6.96	5,789	1.30	1.61	1.29
	16 (4.9)	20	6.97	5,831	1.36	1.57	1.32
Average			6.77	5,331 (36 756 kPa))	1.29 (8.9 GPa)	1.56 (10.7 GPa)	1.25 (8.6 GPa)

For the lodgepole 2 by 4 (5 by 10 cm) lumber, the average Ec was 1.29×10^6 (8.9 GPa), with a range from 0.75×10^6 to 1.90×10^6 (5.17 to 13.1 GPa) the average Esw was 1.56×10^6 (10.7 GPa), with a range from $0.87 X 10^6$ to 2.23×10^6 (6.00 to 15.38 GPa); and the average Es was 1.25×10^6 (8.6 GPa), with a range from 0.49×10^6 to 1.90×10^6 (3.38 to 13.10 GPa). The average modulus of rupture was 5,331 psi (36 756 kPa).

The results of the nondestructive and destructive tests for western white pine are summarized by piece length in table 2. The average Ec was 1.54×10^6 (10.6 GPa), with a range from 0.54×10^6 to 2.49×10^6 (3.72 to 17.17 GPa); the average Esw was 1.81×10^6 (12.5 GPa) and the range from 0.64×10^6 to 2.79×10^6 (4.41 to 19.24 GPa) and the average Es was 1.29×10^6 (8.9 GPa), with a range from 0.58×10^6 to 2.14×10^6 (4.00 to 14.75 GPa). The average modulus of rupture was 4,557 psi (31 419 kPa). For western white pine, the Wood Handbook (1974) reports an average modulus of rupture value of 4,700 psi (32 405 kPa) and an average modulus of elasticity value of 1.19×10^6 psi (8.2 GPa).

The white pine dimension lumber had been graded and the results, summarized by this characteristic, are shown in table 3. The table shows a decrease in average nondestructive and destructive test values associated with the visual grades, construction grade having the best values, economy grade the poorest.

Table 2.—Results of nondestructive and destructive tests on western white pine dimension lumber cut from dead-tree logs

			Average				
					Modulus of elasticity		
Size	Length	No. of pieces	Moisture content	Modulus of rupture	Computer	Stress wave	Static
Inches (cm)	*Feet (m)*		*Percent*	*Psi*	*Million psi*		
2 × 4 (5 × 10)	8 (2.4)	4	6.0	3,972	1.57	1.84	1.44
	10 (3.1)	19	6.0	4,031	1.39	1.76	1.31
	12 (3.7)	46	6.0	4,003	1.55	1.86	1.37
	14 (4.3)	57	6.0	5,102	1.57	1.86	1.34
	16 (4.9)	112	6.0	4,616	1.54	1.77	1.23
Average			6.0	4,557 (31 419 kPa)	1.54 (10.6 GPa)	1.81 (12.5 GPa)	1.29 (8.9 GPa)

Table 3.—Results of nondestructive and destructive tests on western white pine dimension lumber, by grade, cut from dead-tree logs

		Average				
				Modulus of elasticity		
Grade	No. of pieces	Moisture content	Modulus of rupture	Computer	Stress wave	Static
		Percent	*Psi*	*Million psi*		
Construction	57	6.0	5,719	1.63	1.86	1.40
Standard	84	6.0	4,964	1.65	1.91	1.39
Utility	62	6.0	3,653	1.41	1.68	1.14
Economy	35	6.0	3,286	1.35	1.70	1.14
Average		6.0	4,557 (31 419 kPa)	1.54 (10.6 GPa)	1.81 12.5 GPa)	1.29 (8.9 GPa)

The test results for both species were subjected to regression analysis (tables 4 and 5) for the lodgepole and western white pine, respectively. In these tables the r^2 values are a measure of the variation explained by the regression equations and indicate the predictive capability of the equations. For the lodgepole pine lumber, the Ec and Esw test results had an r^2 of 0.90 for 2-by-6-inch (5-by-15-cm) pieces and an r^2 of 0.88 for the 2-by-4-inch (5-by-10-cm) lumber. Ec versus Es and Esw versus Es both had an r^2 of 0.76. The lowest r^2 values were obtained when the nondestructive test data were used to predict the modulus of rupture.

Table 4.—Results of regression analyses of nondestructive and destructive test data of lodgepole pine dimension lumber made from dead-tree logs

	Variables		Number of	Regression equation			
Size	Abscissa	Ordinate	specimens	Intercept	Slope	r^2	r
2 × 6 in (5 × 15 cm)	E-computer Ec	E-stress wave Esw	38	-0.038	1.237	0.90	0.95
	E-computer Ec	E-static Es	38	-.360	.976	.76	.87
	E-computer Ec	Modulus of rupture Mor	38	-632.9	4067.0	.46	.68
	E-stress wave Esw	E-static Es	38	.059	.750	.76	.87
	E-stress wave Esw	Modulus of rupture Mor	38	-578.4	3328.9	.53	.73
2 × 4 in (5 × 10 cm)	E-computer Ec	E-stress wave Esw	110	.132	1.106	.88	.94
	E-computer Ec	E-static Es	110	-.130	1.608	.76	.87
	E-computer Ec	Modulus of rupture Mor	110	-2597.1	6174.5	.51	.71
	E-stress wave Esw	E-static Es	110	-.093	.860	.69	.83
	E-stress wave Esw	Modulus of rupture Mor	110	-2158.2	4829.6	.43	.66

Table 5.—Results of regression analyses of nondestructive and destructive test data from western white pine dimension lumber made from dead trees

	Variables		Number of	Regression equation			
Size	Abscissa	Ordinate	specimens	Intercept	Slope	r^2	r
2 × 4 in (5 × 10 cm)	E-computer Ec	E-stress wave Esw	238	0.417	9.906	0.81	0.90
	E-computer Ec	E-static Es	238	.148	.756	.64	.80
	E-computer Ec	Modulus of rupture Mor	238	-1063.2	.756	.32	.57
	E-stress wave Esw	E-static Es	238	.015	.717	.58	.76
	E-stress wave Esw	Modulus of rupture Mor	238	-614.1	2860.322	.20	.45

For western white pine the results were the same, the nondestructive test methods had an r^2 of 0.81 and the lowest r^2 values were obtained when the nondestructive test results were used to predict the modulus of rupture.

The results of regression analysis of test data obtained from green-tree lumber of other species are shown in table 6. The developmental work on the nondestructive testing methods had indicated the species effect to be minimal. The data of table 6 show that nondestructive evaluation of green-tree lumber has a great deal of promise, with fairly high r^2 values. The r^2 values for the dead- and green-tree lumber are shown in table 7 and graphs of some of the regression lines are shown in figures 1 and 2. The r^2 values show that nondestructive testing methods can be used to evaluate dead-tree lumber.

Table 6.—Results of regression analyses of nondestructive and destructive test data from dimension lumber made from green trees

Size	Variables		Number of specimens	Regression equation			
	Abscissa	Ordinate		Intercept	Slope	r^2	r
[1]2 × 8 in (5 × 20 cm)	E-computer Ec	E-static Es	44	0.036	0.964	0.96	0.98
	Modulus of Rupture Mor	E-computer Ec	24	-4.440	5560.0	.79	.89
[2]2 × 6 in (5 × 15 cm)	E-stress wave Esw	E-static Es	40	-.105	1.046	.90	.95
	E-computer Ec	E-stress wave Esw	40	.074	.969	.93	.97
[3]2 × 4 in (5 × 10 cm)	E-computer Ec	E-stress wave Esw	107	.250	.940	.83	.91
	E-computer Ec	E-static Es	107	.110	.773	.62	.79
	E-static Es	Modulus of rupture Mor	107	2416.0	2815.0	.17	.41

[1] Douglas-fir data obtained from a report by Marra and others. (1966).
[2] Douglas-fir data obtained from a report by Pellerin (1965).
[3] Hemlock-fir data obtained from a report by Hoyle (1977).

Table 7.—Comparison of the regression coefficients for dead- and green-tree dimension lumber of different species evaluated by nondestructive and destructive test methods

Size	Variables	Dead lodgepole		Dead white pine		Green[1]	
		r^2	r	r^2	r	r^2	r
2 × 6 in (5 × 15 cm)	Ec - Esw	0.90	0.95			0.93	0.97
	Ec - Es	.76	.87				
	Ec - Mor	.46	.68				
	Esw - Es	.76	.87			.90	.95
	Esw - Mor	.53	.73				
2 × 4 in (5 × 10 cm)	Ec - Esw	.88	.94	.81	.90	.83	.91
	Ec - Es	.76	.87	.64	.80	.62	.79
	Ec - Mor	.51	.71	.32	.57		
	Esw - Es	.69	.83	.58	.76		
	Esw - Mor	.43	.66	.20	.45		

[1] The 2 × 6 in values were obtained for Douglas-fir by Pellerin (1965); the 2 × 4 in values were obtained for hemlock-fir by Hoyle (1977).

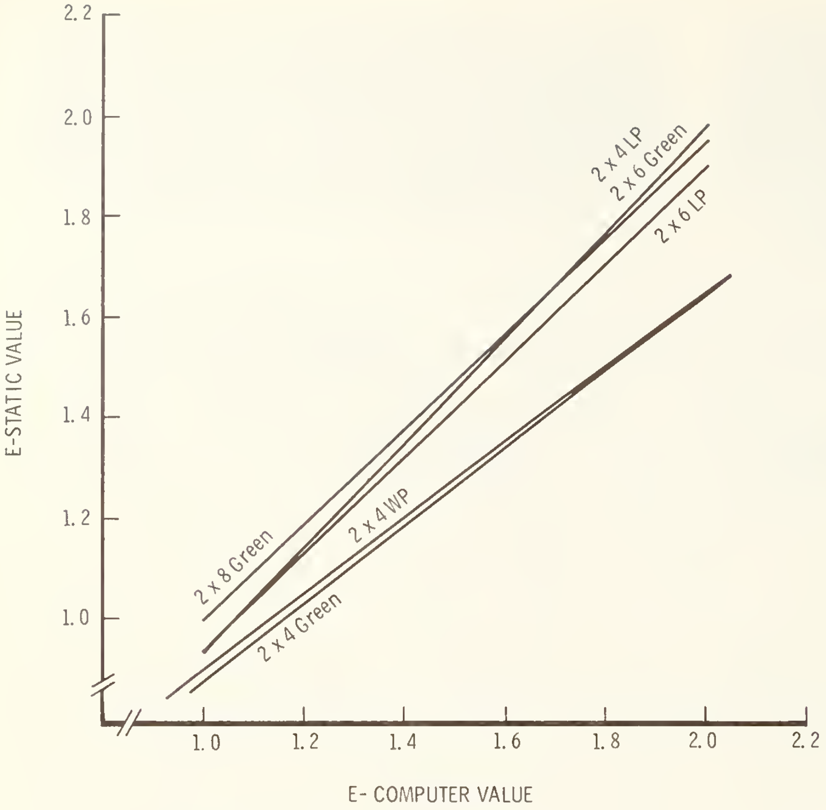

Figure 1.—Regression lines showing the relationship between E-static and E-computer values for dimension lumber obtained from green and dead lodgepole and western white pine trees.

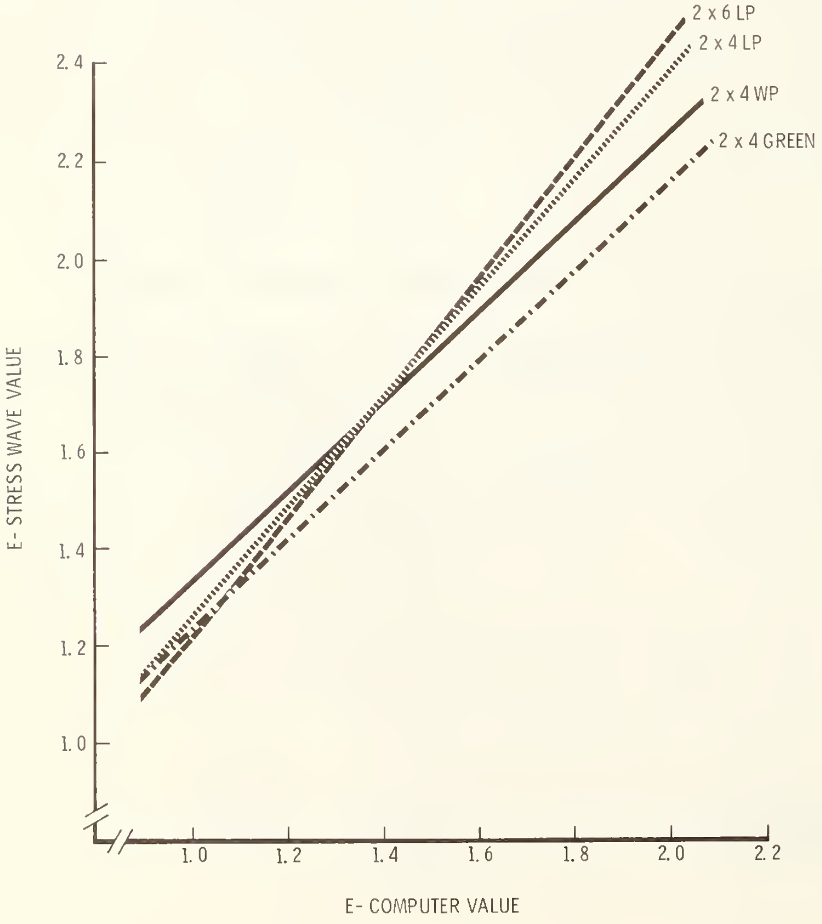

Figure 2.—Regression lines showing the relationship between E-stress wave values and E-computer values for dimensional lumber obtained from green and dead lodgepole and western white pine trees.

CONCLUSIONS

The results of this study indicate that dead-tree lumber can be tested nondestructively by the E-computer and the longitudinal stress-wave methods. Regression analyses of the test data showed the two nondestructive test methods adequately predicted modulus of elasticity for both lodgepole and western white pine. Also, the results from the two methods were closely related. The lowest r^2 values were obtained when the nondestructive test data were used to predict the modulus of rupture.

Nondestructive test data for the western white pine lumber were in general agreement with visual grades.

PUBLICATIONS CITED

American Society for Testing and Materials.
1974. Annual Book of ASTM Standards. Standard methods for testing clear specimens of timber. Philadelphia, Pa.

Galligan, W. L., R. F. Pellerin, and M. T. Lentz.
1967. Longitudinal vibration of logs for prediction of lumber quality. Off rep., Wash. State Univ., Pullman.

Hoyle, R. J.
1977. Mechanical properties of structural lumber input data for reliability analysis of the metal plate truss phase III — experimental. Res. Rep. 77/5755. Wash. State Univ., Pullman.

Kaiserlik, J. H., and R. F. Pellerin.
1977. Stress wave attenuation as an indicator of lumber strength. For. Prod. J. 27(6):39-43.

Marra, G. G., R. F. Pellerin, and W. L. Galligan.
1966. Nondestructive determination of wood strength and elasticity by vibration. Holz als Roh und Werkstoff 24(5):460-466.

Pellerin, R. F.
1965. A vibrational approach to nondestructive testing of structural lumber. For. Prod. J. 15(3):93-101.

Pellerin, R. F., and J. W. Kern.
1974. Stress wave analysis of logs. Res. Rep. 74/5795. Wash. State Univ., Pullman.

Sinclair, S. A., T. E. McLain, and G. Ifju.
1979. Strength loss in small clear specimens of beetle-killed southern pine. For. Prod. J. 29(6):35-39.

United States Department of Agriculture.
1974. Wood handbook: wood as an engineering material. U.S. Dep. Agric. Handb. 72 (rev.). U.S. Gov. Print. Off., Washington, D.C.

Lowery, David P., and Roy F. Pellerin.
1982. Evaluation of dimension lumber made from dead-tree logs. USDA For. Serv. Res. Pap. INT-286, 7 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Dimension lumber cut from dead lodgepole pine and western white pine trees was evaluated nondestructively and destructively. Analysis of test results showed no marked difference in the moduli of elasticity between lumber cut from dead-tree logs and live-tree logs.

KEYWORDS: nondestructive testing, dead trees, dimension lumber, strength properties

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